

Sleep Onset as a Function of Auditory Stimulation
Rates, Response Requirements, and
Novelty of the Environment

By

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SLEEP ONSET AS A FUNCTION OF AUDITORY STIMULATION RATES,
RESPONSE REQUIREMENTS, AND NOVELTY OF THE ENVIRONMENT

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The purpose of this study was to examine latency of sleep onset as a function of rate of auditory stimulation, response requirement, and responses competing with sleep. All stimuli were 500 Hz tones of 1 s duration and 60 db intensity presented at a rate of 30, 15, or 5 per minute. The response requirements were: none, count the tone, or breathe in rhythm with the tone. With each S participating in the experiment for two consecutive days, two levels of responses competing with sleep were obtained. Fifty-four male students in an introductory psychology course participated as SS, with six randomly assigned to each Condition x Rate combination. After each S was wired for an EEG recording he was instructed to rest on his back and go to sleep in the dark, soundproofed testing room. Sessions were 45 minutes long and conducted between 2:30-4:30 p.m.

Results indicated that with no response demands and when Ss counted the tone, the latency of sleep onset for the 15 per minute rate tone was significantly shorter than for the 30 or 5 per minute rates. Sleep onset was faster on the second day an S participated in the experiment, and breathing rates approximated tone rates only when Ss were instructed to breathe with the tones. The curvilinear relationship between tone rate and latency of sleep onset indicated sleep promoted by monotonous stimulation is not solely the result of habituation to the stimulus, but also due to cortical inhibitory processes.

INTRODUCTION

Sleep is a natural, complex, generalized response to both internal and external environmental cues. Anecdotally, an important environmental clue for sleep is a boring situation. (Experimental attempts to establish that monotonous sensory stimulation induces sleep have been infrequent and the results inconsistent.) Perhaps the earliest proponent of the hypothesis was Sidis (1908), who claimed sleep resulted from a reduction of the variability of sensory impulses, rather than a reduction in amount of stimulation. He produced behavioral sleep in guinea pigs, cats, dogs, and children by limiting bodily movements and providing either a monotonous click of a metronome or singing some ditty. In a repetition of Sidis' experiments, Kleitman (1928) concluded immobilization, not the monotonous stimulus, was crucial in promoting sleep. Immobilization led to muscular relaxation which he considered the sine qua non for sleep induction (Kleitman, 1963, p. 196). Kleitman's statement that no monotonous stimulation was necessary was justified, but his data do not allow him to state that monotonous stimulation

could not induce sleep, since he did not provide a monotonous stimulation-immobilization control.

Coriat (1912) also concluded that muscular relaxation was the prerequisite for sleep and monotonous stimulation was unnecessary. When relaxed, his SS fell asleep in about 15 minutes whether a monotonous tone was sounded or not. When SS were made to maintain muscular tension, no sleep ensued even with a monotonous tone. His procedures made it impossible for the tone to produce relaxed muscles, and therefore left tenable the hypothesis that monotonous stimulation induces sleep by aiding muscular relaxation.

Addressing this problem, Lovell and Morgan (1942) concluded that monotonous stimulation did produce muscular relaxation and in this way mediated sleep. The monotonous stimulation consisted of a 60 Hz tone sounded both faster and slower than an S's breathing rate, ranging from 10 to 25 times a minute. A significant rise in palmar skin resistance beyond a basal resting level was the criterion for relaxation. All SS were assured of the harmlessness of the experiment and then seated in a chair for 10 to 15 minutes to obtain a basal resting level. Ten control SS remained undisturbed in the chair for 10 additional minutes. Experimental SS remained in the chair for 20 additional minutes, receiving the stimulation faster than their respiration rate during

one 10 minute period, and slower in the other period. Order of rate presentation was counterbalanced. In addition, half of the experimental Ss were told to relax, and the remainder was given no such instructions. The results were that respiration rates of experimental Ss approximated the stimulus rate. Significant relaxation was observed, but it was independent of tone rate. Control Ss showed no change in respiration nor increased relaxation. Since the group instructed to relax did not show any differences in relaxation from the group having no such directives, Lovell and Morgan regarded suggestion as inoperative. Nine out of their 24 Ss fell asleep during one of the 10 minute periods and all but three Ss admitted feelings of drowsiness. They concluded that responses to monotonous stimulation, such as changes in respiration rate, aid muscular relaxation and in this manner mediate sleep.

It would be surprising if the experimental Ss did not relax, since they were in the chair for at least 30 minutes. Therefore, Lovell and Morgan's conclusions were based primarily on the control group, which participated for only 20 minutes, showing no increase in relaxation. The difference in the experimental and control groups, moreover, was not limited to the presence or absence of monotonous stimulation. It included the presence or absence of knowing what to

expect. The control group was never told what would occur in the 10 minute interval and possibly remained alert waiting for something to happen, rendering relaxation impossible. Even if the control ss had concluded nothing was going to happen, after the baseline recording they were in the chair for only 10 minutes and could not be expected to achieve the same level of relaxation as the ss who were able to relax for 20 minutes. Because of their design, Lovell and Morgan did not indicate whether experimental ss showed increased relaxation after 10 minutes, but only after 20. It is possible that no s showed increased relaxation after 10 minutes. Because of these problems, the hypothesis that monotonous stimulation can aid relaxation, thereby mediating sleep, remained untested.

Relaxation studies not concerned with monotonous stimulation provide some information. Sleep has been shown to depend upon the attainment of a specific level of relaxation (Jacobson, 1938, p. 38; Kahn, Baker, & Weiss, 1968; Miller, 1926). Hodes (1961, 1962) and Zung (1970) have attributed the sleep to decreased proprioceptive stimulation of the cortex as a result of decreased muscle tension. The purpose of relaxing is to reduce not only proprioceptive stimulation of the ascending reticular activating system (ARAS), but also cortical stimulation of the ARAS from reflections

(Jacobson, 1938, p. 38; 1962, p. 87). This suggests how monotonous stimulation might induce sleep. For Ss who have difficulty shutting off cortical excitatory impulses to the ARAS, a monotonous stimulus becomes a focal point. Attending to this stimulus effectively shunts other stimuli, peripheral and cortical. Gradually the monotonous stimulus loses its ability to maintain wakefulness because it becomes a non-informational, non-excitatory stimulus, and sleep ensues.

Pavlov (1928, p. 311) attributed a more active role to the stimulus. He asserted that monotonous stimulation acted upon an organism's central nervous system to induce sleep. He observed that a CS presented without the UCS inevitably led to drowsiness and sleep. His explanation was that repetitive stimulation of any point in the cortex gives rise to inhibition which irradiated over the cortex. Thus, sleep was inhibition that had spread over the cerebrum, the entire hemispheres, and even into the lower midbrain.

In a series of experiments, Oswald (1959) investigated transmarginal inhibition, a mechanism to protect an S from excessively strong stimuli. In one experiment Ss rested on a couch in a normally lighted room for three sessions, each lasting 15-30 minutes. The Ss were required to click a switch when they heard a tone initially set at the level of the absolute threshold for loudness. The tones were

presented at regular rates of 6, 12, or 20 per minute. The rate was constant within a single session. Two tendencies were observed: (a) sleep and alertness appeared to alternate regularly with the rate of the signals, and (b) there was a general drift toward sleep. The level of sleep for Ss was identified by referring to sample EEG records. Respiration rates tended to synchronize with the rhythm of stimulation.

In a third experiment the Ss lay on a couch and moved their hands and feet in time with recorded jazz or blues. EEG signs of sleep appeared for long periods, even though movement continued. Again, alertness and sleep fluctuated with the rate of the rhythm. Sleep appeared in some instances during loud music, but more frequently when a smooth piece followed a violent selection. There was a tendency for respiration to become regular and related to limb movements.

To answer criticisms that sleep would not have been possible if Ss had not closed their eyes, Oswald (1960) reported further experiments in which Ss had their eyes glued open. For each S the entire environment was dominated by one rhythm of stimulation. A 60 minute tape of non-stop blues music was played with brief 800 Hz tones pulsating with each beat of the musical rhythm. Visual stimulation from four 60 watt bulbs also pulsated with the rhythm, as well as electric shocks to the leg of the S. The first

three volunteers rested on a couch, making no movements. The first S was sleep deprived, confounding the effects of rhythm on sleep latency. The second S participated in the experiment between 9:00 and 10:00 p.m. and showed low voltage slow waves after 8 minutes. A sleep latency of 8 minutes was also obtained for the third S, with the experiment conducted in the afternoon. Information on Ss' latencies in a quiet environment was not obtained, which would be prerequisite for an evaluation of the effects of the rhythm on sleep latency. Two additional Ss sat in a chair, received no shocks, and moved arms and feet in time with the music and lights. The first sign of slow wave EEG activity was after 10 minutes for one S and 15 for the other. Episodes of light sleep alternated with wakefulness for each S. Oswald's experiments clearly demonstrated that people can go to sleep when subjected to repetitive monotonous stimulation, but do they sleep because of or in spite of such stimulation? A control condition of no stimulation would be necessary to answer this question. Oswald (1966, p. 46) claimed this control was studied in an experiment in Marseilles. Some of 150 Ss underwent a 4 minute period of monotonously recurring lights or noises and over a third of them went to sleep. By contrast, others who experienced a

comparable period of silent darkness hardly ever went to sleep. It is impossible to evaluate this study because these were the only details presented.

Gastaut and Bert (1961) interpreted habituation to repeated stimuli as a form of protective inhibition, and attempted to study this inhibition by examining habituation of the blocking of the alpha rhythm with repeated stimuli. Each S participated in five experimental sessions of approximately 4 minutes each, except the first which was a 7 minute rest period. This was followed by a period of habituation of the alpha rhythm by visual stimuli, given for 4 s every 20 s with a 75 watt lamp placed 1.5 m from the S's eyes. The third session consisted of habituation of blocking of the alpha rhythm by auditory stimuli presented at the same rate as the visual stimulus. Next came a period of mental addition and subtraction of increasing difficulty. A final rest period concluded the experiment. Each of the 91 SS received the experimental treatments as outlined. In addition, 11 SS repeated the procedure each week for five to seven weeks. A third group of SS with no or poor alpha was considered a control group. Gastaut and Bert's results indicated that: (a) EEG signs of sleep occur most frequently during periods of habituation of blocking of the alpha rhythm, (b) there is a positive correlation between rapidity

of habituation of blocking and appearance of signs of sleep, and (c) there is a facilitation of the habituation when the experiment is repeated.

It is necessary to evaluate Gastaut and Bert's methods. They gave only one clue to the meaning of "signs of sleep"; reporting the frequency of the occurrence of the stage of spindles and K complexes, they indicated that all of their signs of sleep, except for 12 instances, must be stage 1. No statistical tests were presented and there was no proper control group. The rest periods might have been a control condition, but the same sequencing of events was used for all ss, and differences attributable to length of time in the experimental situation could not be evaluated. Prior to each rest period, the s was engaged in active behavior, but each habituation period was preceded by rest, with or without stimulation.

Statements that monotonous stimulation caused sleep, based on studies she considered uncontrolled, led Tizard (1966) to investigate the amounts of sleep recorded during periods of auditory stimulation compared to equal silent periods, instructional effects on the amount of sleep, and the result of varying stimulus intensity. Each of 12 ss was seen for two sessions at 6 to 7 day intervals, always at 2:00 p.m., for three 8.5 minute periods.

Two of the periods contained auditory stimulation, and one was a control period. In the beginning, SS were told there would be periods of intermittent sounds and others when nothing would happen. They were instructed to keep their eyes closed throughout. At the start of the control period, SS were told there would be no sounds and to go to sleep if they liked. Before one stimulation period they were asked to listen very carefully for the sounds and press a response bulb in their hand each time they heard a stimulus. Before a second stimulation period they were instructed to ignore sounds and sleep if they liked. The order of presentation for the three periods was randomized with a 3 x 3 Latin Square design. Half of the SS were given unpleasantly loud sounds in the first session and quiet sounds in the second, with this order reversed for the other half. In order to avoid habituation to one tone, four different frequencies (800, 900, 1,000, 1,100 Hz) were used in the four stimulation periods. The duration of a stimulus was 4 s and the interval between stimuli was 20 s.

The EEG record of each 500 s experimental period was divided into 10 s epochs and evidence of sleep (Locmis, Harvey, & Hobart, 1937, used as classification) assessed in the first and every subsequent fifth epoch, resulting in 10 measurements. During stimulation periods epochs were

always chosen before a stimulus. There was no significant difference in amount of sleep between the control ss and those instructed to ignore the sound, but more sleep was recorded in both of these ss than for the ss who attended to the tones. The only other significant finding was that amounts of sleep increased across weeks. In the control and ignore sounds conditions, eight ss reached stage C sleep during the first session and all 12 in the second session. Tizard concluded that the Pavlovian theory of the sleep-promoting effects of rhythmic stimuli was not supported, but a monotonous environment did favor sleep.

Tizard's conclusion that monotonous stimulation per se does not promote sleep is consistent with the hypothesis that the S's response to the stimuli is crucial. When a motor response was required, S was asked to "listen very carefully" for the sound. In effect, this condition became a signal detection task and was not likely to produce sleep in 8.5 minutes. Implicit in the instruction to listen carefully is the instruction to stay awake. Thus, while concluding sleep produced in studies using monotonous stimulation was due to instructions, Tizard demonstrated that sleep could also be prevented by instructional manipulations. In addition to the tone orienting instructions, the response of bulb pressing was a possible source of stimulation

maintaining wakefulness.

More recent evidence indicates monotonous stimulation promotes sleep even with no response requirement for the S. Bohlin (1971) investigated the effects on arousal and sleep onset of a 1,000 Hz tone of 4 s duration and 80 db intensity, presented with a mean inter-stimulus interval of 30 s, varied within a range of 20-40 s. Thirty SS were exposed to each condition of no stimulation and monotonous stimulation, with the order of conditions balanced and a week interval between sessions to minimize transfer effects. The SS were told the experiment was a study of physiological response to auditory stimulation, and no overt responses were to be given. The possibility of sleep was acknowledged, but there were no direct instructions to sleep. Mean latency of sleep onset was determined by EEG records and was significantly shorter for the monotonous stimulation than the control condition.

In a second experiment, in addition to no stimulation, three monotonous stimulation conditions were obtained by using the same stimulus but with three inter-stimulus intervals: 5-15 s with a mean of 10 s, 20-40 s with a 30 s mean, and 50-80 s with a 65 s mean. Forty-eight SS were randomly assigned to each condition, and given the instructions used for the first experiment. The mean latency of sleep onset

for all stimulation rates was shorter than that for the no simulation condition. Compared to the longest inter-stimulus interval, the shortest produced a significantly shorter mean latency of sleep onset.

In a series of experiments designed to examine the influence of a repeated tone on latency of sleep onset, Webb and Agnew (1971) studied the following conditions: silence, monotonous sound, low level tones, low level tones plus counting, low level tones plus eye opening, and silence with sleep deprivation. The monotonous sound was a recording of a fan motor, and low level tones were 800 Hz tones of 70 db intensity and 2 s duration with a 2 s interval between tones. All Ss were asked to sleep, and those asked to count were required to do so at the beginning and end of each tone. The Ss in the eye blink condition were required to close their eyes when the tone began and open them at the end of each tone. Eight different Ss served in each condition for 5 consecutive days, with each session lasting 30 minutes. For the sleep deprivation condition, eight Ss arrived at the lab at 11:00 p.m. the night before the experiment and were kept awake until the experimental session at 10:00 or 11:00 a.m. the next morning, which were the times all Ss attempted sleep. Results indicated neither the stimulation conditions nor silence could produce sleep latencies as short as the

sleep deprivation condition. Excluding sleep deprivation, the tone only condition induced sleep fastest, significantly shorter than silence and the eye blink condition. Latency of sleep onset was reduced across days for all conditions except silence, with most of the reduction occurring from Day 1 to Day 2.

Many studies have attempted to establish that monotonous stimulation promotes sleep, and in the majority of them the data were called into question due to errors in experimental design. The more recent studies by Bohlin (1971) and Webb and Agnew (1971) corrected for the previous errors and provide evidence that a repeated tone can facilitate sleep onset. These studies suggest the following variables are important determinants of the latency of sleep onset under auditory stimulation: the S's response to the stimulus, rate of stimulus presentation, and whether or not the S has tried to sleep with auditory stimulation previously. Although the effects of a response requirement and rate change have been investigated in these experiments, it is possible that the optimal rate depends on an S's response. The purpose of the present experiment was to examine this possibility and include a response which approximates what an S usually does naturally in going to sleep, i.e., breathe regularly. Any response requirement should eliminate irrelevant cognitive

responses, force the monotony of the repetitive tone on the S, and in this way mediate sleep. Therefore, when irrelevant competing responses are at a maximum, such as the first time an S serves in the experiment, a condition with a response requirement should facilitate sleep more than one with tones only. With reduced competing responses, in this case the second time the S participates in the experiment, there should be no differences between conditions with or without a response requirement. The present experiment also tested these hypotheses.

METHOD

Overview. A $3 \times 3 \times 2$ factorial experiment with repeated measures on the third factor was used to investigate effects of the rate of auditory stimulation on latency of sleep onset, the S's response to stimuli, and responses competing with sleep. The stimuli were 500 Hz tones of 1 s duration and 60 db intensity, presented at a rate of 30 (R-30), 15 (R-15), or 5 (R-5) per minute. The response conditions studied were: tone only with no response (T), count the tone (T-C), and breathe in with the tone (T-B). With each S participating in the experiment for 2 consecutive days, two levels of responses competing with sleep were obtained.

Subjects. Male students enrolled in an introductory psychology course participated as Ss. The first 54 to volunteer were selected, and six were randomly assigned to each condition x rate combination. Although two Ss appeared at each of the three times 2:30 p.m., 3:15 p.m., and 4:30 p.m., the data were considered as six replications of each condition x rate x day combination. This was done to simplify

the analyses, since initial computations, blocking for time of day, indicated no time effects were significant. When they volunteered for the experiment, all Ss were instructed to refrain from alcoholic or caffeinated beverages on the days of the experiment and to avoid altering their usual sleeping schedule for the 2 days preceding the experiment. In addition, they were asked to eat lunch at least 2 hrs before the time they would be attempting to sleep. The Ss ranged from 18 to 27 yrs (mean = 19.87, SD = 1.48).

Procedure. The Ss arrived at the lab 30 minutes prior to an experimental session, and electrode application and other preparations provided a common presleep experience. Each S was wired so that an EEG recording could be obtained between F_1 - F_7 and O_3 - O_zP_z , as determined by the International 10-20 System for electrode application. The Grass Model VI EEG was calibrated for 7.5 mm = 50 μ v on all channels. The recordings were made at a paper speed of 30 mm/s. A mercury strain gauge was connected around the S's abdomen and a Parks Model 270 Plethysmograph monitored respiration rates on the EEG output. An S lay supine on a bed in a dark, soundproofed room and was instructed to sleep. Each S was told to make no more body movements than absolutely necessary, since these interfered with the recordings. Tape-recorded supplemental instructions appropriate to the experimental condition (see

Appendix A) were then played. Tones were presented continuously at the preassigned rate throughout the 45 minute session, and speakers placed above and on each side of the S insured a constant auditory intensity level regardless of the S's orientation. Each S was awakened at the end of the experimental period and given a questionnaire designed to determine if he followed instructions (see Appendix B). Identical procedures were followed for the second experimental session.

After each experimental period, the questionnaires were examined to insure that each S had followed instructions. Of primary interest were items concerning any difficulty going to sleep at home under normal conditions and recent happenings which might have affected sleep onset. Two Ss were dropped from the experiment because of positive responses to the latter question. Even though every person told to breathe with the tone reported difficulty doing so, answers indicated that all tried to follow the instructions. All of the Ss in the T-C Condition reported counting, and half of them related problems with the requirement.

Scoring. The measures of dependent variables were derived from the EEG records which were evaluated using a blind scoring technique. EEG records were first scored in 1 minute epochs for onset of brief sleep, i.e., less than

30 s of 8-12 Hz occipital activity per epoch. The 11 Ss who failed to sleep were assigned the maximum latency possible, which was 45 minutes. Scoring reliability was assessed by correlating independent ratings of 30 randomly selected records evaluated by a second scorer. The Pearson r was .91.

In some instances an epoch was classified as sleep and shortly afterwards an S woke up and remained awake for the entire session. Since this sleep response is different from one where an S remains asleep, EEG records were also scored for onset of extended sleep. The criterion for sleep onset was identical to that used for brief sleep, but it was applied only to the period before which an S went to sleep and remained asleep for the duration of the experiment, or to the first epoch when S reached stage 2 (Dement & Kleitman, 1957). With these criteria, no extended sleep period was less than 7 minutes long. The 27 non-sleepers were evenly distributed among conditions, and each was assigned the maximum latency of 45 minutes. Inter-scorer reliability was again high (r = .99).

Sleep records were then scored for deepest stage of sleep attained. Since breathing rates would change with sleep onset, they were scored only for the first 8 minutes. The average rate per minute was calculated for four 2 minute Blocks.

RESULTS

General. For onset of brief and extended sleep, planned comparisons were made with a t test for the Condition x Rate (22 df) and Condition x Day (34 df) interactions. The t value is always given first in parentheses, followed by the alpha level when less than .10. When interaction comparisons were not significant, significant F ratios for the appropriate main effects were reported. The bound on error of estimation, i.e., 2 SD, was computed when means were significantly different.

Since analysis of variance procedures were inappropriate for the depth of sleep measure, a contingency table was set up with depth of sleep for rows and the Condition x Rate combinations for columns. A Chi-squared statistic could not be computed since the expected cell frequencies were too small (see Mendenhall, 1967, p. 262). A descriptive analysis was presented for this interaction. For the Condition x Day interaction, differences between Conditions were analyzed separately for Days 1 and 2 using the normal approximation to the binomial. The proportions considered were ss remaining awake and those reaching stage 2 or deeper.

The primary purpose of examining breathing rates was to ascertain that ss followed instructions. The significant condition x Rate x Block interaction was investigated with Tukey's post hoc comparison suggested by Kirk (1969).

Brief sleep. The analysis of variance for onset of brief sleep is summarized in Table 1. For Condition T, R-15 produced shorter latencies than both R-30 (2.46, .015) and R-5 (1.81, .05). In the T-C Condition, R-15 was more efficient in inducing sleep than R-5 (1.61, .035), but not R-30 (1.24). R-15 was not different from R-30 (.52) or R-5 (.71) for T-B. Table 2 contains the means for these comparisons, and the bound on error for each was 7.97. Planned comparisons for Conditions at each rate indicated T-C produced shorter latencies than T for R-30 (1.45, .085), with no other differences. No differences existed for any of the Condition x Day interaction planned comparisons (see Table 3 for the appropriate means). A reliably shorter period was required for sleep onset on Day 2 (15.18 minutes) than on Day 1 (18.99 minutes). For Day means the bound on error was 2.37.

Since Bohlin's (1971) results indicated a linear relationship between latency of brief sleep onset and tone rate, sums of squares for Rates were parcelled into components for linear (SS = 13.92) and quadratic trends (SS = 1457.78). The $F_{1,45}$ values for the linear and quadratic trends were

Table 1

Summary of Analysis of Variance of
Time to Onset of Brief Sleep

Source	SS	df	MS	F	P
Conditions (C)	283.40	2	141.70	<1	
Rates (R)	1471.70	2	735.85	3.86	<.04
C x R	407.27	4	101.82	<1	
<u>Ss</u> w gps	8575.57	45	190.57		
Days (D)	392.89	1	392.89	5.11	<.04
C x D	.02	2	.01	<1	
R x D	20.92	2	10.46	<1	
C x R x D	500.16	4	125.04	1.63	
D x <u>Ss</u> w gps	3458.10	45	76.85		

Table 2

Mean Latency of Onset of Brief and Extended
Sleep for the C x R Interaction

<u>Conditions</u>	<u>Rates</u>		
	R-30	R-15	R-5
T	24.87*	11.01	21.18
	29.19**	17.94	27.89
T-C	16.68	9.72	18.77
	24.89	21.09	34.34
T-B	17.80	14.87	18.87
	23.41	24.37	24.96

* Mean number of minutes to onset of brief sleep.

**Mean number of minutes to onset of extended sleep.

Table 3

Mean Latency of Onset of Brief and
Extended Sleep for the C x D Interaction

Conditions	<u>Days</u>	
	1	2
T	20.92*	17.11
	30.40**	19.61
T-C	16.94	13.17
	25.95	27.59
T-B	19.12	15.25
	25.70	20.79

* Mean number of minutes to onset of brief sleep.

**Mean number of minutes to onset of extended sleep.

<1 and 7.65 ($p < .01$), respectively.

Extended sleep. The analysis of variance for extended sleep latencies is summarized in Table 4. For the T Condition, R-15 produced shorter sleep latencies than R-30 (1.59, .065) and R-5 (1.41, .09). In the T-C Condition, R-15 induced sleep faster than R-5 (1.89, .04), but not R-30 (.54). Neither R-30 (.14) nor R-5 (.03) was different from R-15 in the T-B Condition. A study for Condition effects at each rate indicated no significant differences. Condition x Rate means for this variable are also presented in Table 2, and the bound on error for each was 9.69. Examination of the Condition x Day interaction indicated a significant reduction in sleep latencies from the first to the second Days for the T Condition (1.87, .035), with no differences between Days for the T-C Condition (.28) or T-B Condition (1.85). No differences existed between Conditions on either day. Table 3 contains the means for this interaction, each having a bound on error of 5.36.

Depth of sleep. Table 5 contains the deepest stage of sleep attained for the Condition x Rate interaction and Table 6 for the Condition x Day treatments. Examination of Table 5 implies that R-15 was more sleep inducing than R-30 and R-5 for the T Condition, and than R-5 for the T-C Condition. There is no statistical evidence to support

Table 4

Summary of Analysis of Variance of
Time to Onset of Extended Sleep

Source	SS	df	MS	F	P
C	223.98	2	111.99	<1	
R	900.04	2	450.02	1.50	
C x R	1162.01	4	290.50	<1	
<u>Ss</u> w gps	13507.65	45	300.17		
D	592.77	1	592.77	4.58	< .03
C x D	697.54	2	348.77	2.70	< .085
R x D	174.53	2	87.27	<1	
C x R x D	128.02	4	32.00	<1	
D x <u>Ss</u> w gps	5823.56	45	129.41		

Table 5

Distribution of Depth of Sleep Attained
for the C x R Interaction

Deepest Sleep Stage Attained	<u>Conditions</u>								
	<u>T</u>			<u>T-C</u>			<u>T-B</u>		
	R-30	R-15	R-5	R-30	R-15	R-5	R-30	R-15	R-5
0	3*	0	0	0	0	2	1	0	2
1	4	2	4	3	2	6	3	5	1
2-4	5	10	5	9	10	4	8	7	9

*Entries are number of Ss.

Table 6

Distribution of Depth of Sleep Attained
for the C x D Interaction

Conditions	<u>Days</u>			
	1		2	
	Stage 0	Stages 204	Stage 0	Stages 2-4
T	3*	7	3	13
T-C	1	12	1	11
T-B	2	10	1	14

*Entries are number of ss reaching the given stage, but no deeper.

this implication for this dependent variable, but it is in agreement with the findings for brief and extended sleep. For the Condition x Day interaction, on Day 1 more Ss in the Conditions requiring a response (T-C, T-B) reached stage 2 or deeper sleep than those in Condition T ($z = 1.55$, $p < .06$). This comparison was not significant for Day 2 ($z = .21$), nor were similar comparisons for the percentages of Ss remaining awake on Day 1 ($z = .92$) and Day 2 ($z = 1.31$).

Breathing rates. The analysis of variance for breathing rates is summarized in Table 7. Tukey's post hoc comparison of the significant Condition x Rate x Block interaction indicated the following differences at the .05 level (see Table 8 for appropriate means). The Ss in T-B with R-30 maintained breathing rates faster than both the groups told to breathe at slower rates, and those receiving R-30 but not in T-B. These differences were consistent for the four Blocks. For R-5, with Condition T-B breathing rates were reduced compared to T and T-C for the first two Blocks only. Breathing rates were not different for the three instructional Conditions for R-15. For Condition T-B with R-30, breathing rates for Blocks 3 and 4 were significantly slower than for Block 1. For every other Condition x Rate combination, breathing rate changes across Blocks were not significant.

Table 7

Summary of Analysis of Variance
for Breathing Rates

Source	SS	df	Ms	F
C	181.38	2	90.69	<1
R	1430.72	2	715.36	5.88
C x R	3685.88	4	921.47	7.57
<u>Ss</u> w gps	5478.48	45	121.74	
D	44.40	1	44.40	2.76
C x D	8.23	2	4.12	<1
R x D	7.72	2	3.86	<1
C x R x D	27.06	4	6.77	<1
D x <u>Ss</u> w gps	724.33	45	16.10	
Blocks (B)	4.71	3	1.57	<1
C x B	51.88	6	8.65	2.09
R x B	63.51	6	10.58	2.56
C x R x B	143.59	12	11.97	2.89*
B x <u>Ss</u> w gps	559.28	135	4.14	
D x B	4.33	3	1.44	<1
C x D x B	3.05	6	.51	<1
R x D x B	2.63	6	.44	<1
C x R x D x B	6.50	12	.54	<1
D x B x <u>Ss</u> w gps	407.81	135	3.02	

*Significant at .002 level.

Table 8
Mean Breathing Rates

Conditions	Rates	<u>Blocks</u>			
		1	2	3	4
T	R-30	15.08	15.12	14.87	15.75
	R-15	14.96	15.46	16.29	15.62
	R-5	16.21	17.12	16.67	17.12
T-C	R-30	16.54	16.33	16.83	17.75
	R-15	17.21	17.12	16.87	16.39
	R-5	16.62	16.46	16.58	17.08
T-B	R-30	28.33	26.42	24.00	23.67
	R-15	14.79	14.67	14.58	14.58
	R-5	11.37	11.08	11.92	13.29

DISCUSSION

Conditions x Rates. For the three sleep measures, the optimal rate for sleep onset depended on the response requirement, indicating a Condition x Rate interaction. This was due to the fact that breathing with the tone was so difficult that the Rate effect was not significant in this Condition. For the T and T-C Conditions, R-15 was the optimal rate for each measure of sleep. Although T-C tended to be better than T for R-30, the Condition x Rate comparisons indicated that it is more appropriate to discuss these main effects than an interaction, since there is an optimal rate to facilitate sleep, but its influence is minimal with a difficult response requirement.

Rates. The relationship between latency of brief sleep onset and tone rate was curvilinear. A medium rate tone facilitated sleep onset. A very rapidly presented tone produced excessive sensory and probably cortical stimulation, since Ss reported the tone annoyed them. At a slow rate, silence was approached and the tone ceased to serve as the same type of monotonous stimulus. The absolute silence of a soundproofed room produced a monotonous environment relative to the "silence"

an S experiences in his own bedroom and this abnormal lack of sensory stimulation can impede sleep onset.

The results of the rate manipulation confirm Bohlin's (1971) findings that this variable is an important determinant of sleep onset but do not support his conclusion that sleep onset and tone rate are linearly related. However, the rates he investigated were all slower than R-5, the slowest used in the present experiment; thus, the results of the two studies are not entirely comparable.

Conditions x Days. This interaction tested the hypothesis that requiring an S to respond to a repetitive tone would reduce the effect of distracting environmental and cortical stimuli which prevent sleep. On Day 1, the novelty of the experimental situation provided maximum distractions but the effects of these competing stimuli were reduced on Day 2. The hypothesis tested had two parts. The first was that on Day 1 T-C and T-B would produce shorter sleep latencies than T. For the brief and extended sleep measures, Day 1 latencies tended to be shorter for T-C and T-B than for the T Condition, although these differences were not statistically significant. For depth of sleep, the T Condition tended to produce more non-sleepers than T-C and T-B, but these differences were not reliable. However, a significantly greater number of Ss in T-C and T-B reached deep sleep

than those in the T Condition. Therefore, the first time S participated in the experiment, a response requirement reduced the effects of distracting stimuli for only one sleep measure.

The second part of the hypothesis tested was that only in Condition T would a significant reduction in sleep latencies occur from Day 1 to Day 2. For brief sleep, shorter latencies were observed on Day 2 than Day 1 for all conditions, but for extended sleep, only in Condition T was there a reduction in latency from Day 1 to Day 2. The extended sleep results indicated the T Condition was not adequate to reduce the effects of distracting stimuli present on Day 1, but the T-C and T-B Conditions minimized the first Day effect so that no differences in sleep latencies occurred between Day 1 and Day 2. Therefore evidence exists for a Condition x Day interaction. The effects were weak and probably would have been stronger if a situation were created where distractions associated with a response requirement were minimal compared to those of the experimental situation. As it was, responses competing with sleep generated by the novelty of the environment were minimal compared to the distractions created by requiring a response.

Conditions. The weakness of the first Day effect partially accounts for the failure to find Condition differences. An additional explanation is with the T-C

Condition the S placed more emphasis on the instruction to count than to sleep, and had difficulty releasing himself from the response requirement. An additional study (see Appendix C) indicated the T-C Condition could not produce shorter sleep latencies when the S was experimentally released from the response requirement by terminating the tone after the experiment was well under way. Therefore, the release problem cannot be avoided.

The purpose of the T-B Condition was to facilitate sleep onset through relaxation. Lovell and Morgan (1942) observed increased relaxation when respiration rate increased or decreased. Since respiration rates become slower in sleep (Oswald, 1962, p. 170), the slowest rate for T-B required S to approximate one component of the complex sleep response. The difficulties in maintaining extremely slow and fast rates cancelled any advantage of the regulated breathing. Failure for the T-B Condition to affect sleep onset was not due to Ss' ignoring instructions. The significant Condition x Rate x Block interaction for breathing rates indicated Ss maintained the required breathing rates until sleep onset approached. The possibility remains that regulated breathing may facilitate sleep onset when the tone rate is more compatible with this response. But this is unlikely since R-15, a rate 1 or 2 units per minute slower than normal

breathing, tended to increase latency of sleep onset for T-B compared to Conditions T and T-C.

Breathing rates. Although the primary purpose of examining breathing rates was to insure an S followed in-structions, a secondary reason was to determine if tone rate influenced breathing independent of the instructions. Rates for the T and T-C Conditions did not affect breathing rates. The extremeness of R-30 and R-5 probably produced the failure to replicate Lovell and Morgan's (1942) -- findings that breathing rates approximate tone rate. In no instance was the rate of their stimuli more than 10 units different from the normal breathing rate. Both of the extreme rates used in the present experiment were more than 10 units different from normal respiration rates. Supplementing the previous findings, the present results on breathing indicate an upper and lower limit beyond which tone rate cannot be changed and still influence breathing.

Conclusions. There is evidence that a repetitive tone promotes sleep (Bohlin, 1971; Webb & Agnew, 1971), but the effects can be attenuated by instructions, since significantly longer latencies for tones than for silence were recorded when Ss were required to press a response bulb (Tizard, 1966) or blink their eyes (Webb & Agnew, 1971) with the tones. The present experiment and Webb and Agnew's (1971) indicate

a response more compatible with sleep, such as counting the tone, can enhance the effects of the monotonous stimulus. Bohlin (1971) concluded that tone rate was an important determinant of sleep latency, but the present study revealed rate control is weak, since its effects are diminished with a difficult response requirement. The Day effect observed in this and Webb and Agnew's (1971) study cannot be considered strong either, since its control over sleep onset is abated with a proper response requirement. When compared to sleep need (Webb & Agnew, 1971), the three variables manipulated in this experiment exercise minimal control over sleep onset.

The curvilinear relationship between rates and latency of sleep onset suggests a mechanism for sleep promoted by repetitive sensory stimuli. Such sleep is not solely the result of habituation to the stimulus, since the more rapid the frequency of stimulation, the more rapid is habituation (Thompson & Spencer, 1966). Habituation to the tone would have been fastest for R-30, but latency of sleep onset was shorter for R-15. This does not imply that habituation is not important for sleep onset. It is possible that habituation to repetitive stimuli triggers cortical inhibitory processes. Thus, a time interval between habituation to a stimulus and sleep onset exists and corresponds to

the time necessary for inhibitory processes to take over and produce sleep. Any unfavorable attitude on the S's part would interfere with this process. Concerning the localization of inhibitory systems, Moruzzi (1960, 1963) concluded a hypnogenic center for monotonous stimulation was located in the area of the nucleus of the solitary tract. He suggested these synchronizing structures could be driven by repetitive sensory stimuli to reduce EEG arousal and lead to drowsiness by blocking successively the phasic response and tonic activity of reticular neurons. Although these mechanisms are complex and the process can be interrupted by an S's attitudes, there is evidence that monotonous sensory stimuli do promote sleep.

APPENDICES

APPENDIX A
INSTRUCTIONS

Tone

It has been found that a repeated tone will help a person get to sleep. We are trying to get an accurate measure of the efficiency of this condition, and we are measuring your sleep with the electrodes. Try to make no more body movements than are absolutely necessary, since they will interfere with the recordings. When you begin to fall asleep, the volume of the tones will be gradually reduced. Your primary task is to go to sleep. We will wake you at the end of the experimental period.

Tone Count

It has been found that if a person counts a repeated tone to himself for a little while, it will help him get to sleep. We are trying to get an accurate measure of the efficiency of this condition, and we are measuring your sleep with the electrodes. Try to make no more body movements than are absolutely necessary, since they will interfere with the recordings. When you begin to fall asleep the volume of the tones will be gradually reduced. You are to count each tone to yourself until we reduce the volume of the tones. If you should feel drowsy before we reduce the volume of the tones, stop counting and go on to sleep. Your

primary task is to go to sleep. We will wake you at the end of the experimental period.

Tone Breathe

It has been found that if a person breathes with a repeated tone, it will help him get to sleep. We are trying to get an accurate measure of the efficiency of this condition, and we are measuring your sleep with the electrodes. Try to make no more body movements than are absolutely necessary, since they will interfere with the recordings. When you begin to fall asleep, the volume of the tones will be gradually reduced. You are to breathe in with the beginning of each tone until we reduce the volume of the tones. If you should feel drowsy before we reduce the volume of the tones, stop thinking of breathing, and go on to sleep. Your primary task is to go to sleep. We will wake you at the end of the experimental period.

APPENDIX B
QUESTIONNAIRES

Day 1

Tone

Circle T for True or F for False.

I usually have little difficulty falling asleep. T F

I fell asleep in today's experiment. T F

I fell asleep faster than usual in today's experiment. T F

I prefer a quiet room for sleeping. T F

I usually lie awake a long time before falling asleep. T F

I prefer some background noise for sleeping.

If T for above, specify type of noise. _____

Something happened to me recently which affected how fast I fell asleep today. T F

If T for above, explain.

Tone Count

The following questions were added to those asked for the tone condition:

I had difficulty counting the tones. T F

The last number I counted was _____.

I lost count and began counting again. T F

If T for above, number of times was _____.

If T for above, last number counted each time _____.

Tone Breathe

The following questions were added to those asked for the tone condition:

I had difficulty breathing with the tones.	T F
I quit trying to breathe with the tones before the tones were faded out.	T F

Day 2

Tone

Circle T for True or F for False.

I fell asleep in today's experiment.	T F
I fell asleep faster than usual in today's experiment.	T F
Something happened to me recently which affected how fast I fell asleep today.	T F

If T for above, explain.

Tone Count

In addition to the questions asked for the tone condition on Day 2, those used on Day 1 for the tone count group were also included.

Tone Breathe

In addition to the questions asked for the tone condition on Day 2, those used on Day 1 for the tone breathe group were also included.

APPENDIX C

SUMMARY OF STUDY 2

The purpose of Study 2 was to determine if the T-C Condition could be improved by experimentally releasing an S from his response requirement. The SS were 16 alpha dominant male students in an introductory psychology course between 20-27 yrs of age. They were divided equally into No-Release and Release groups. The No-Release SS were instructed to count the tone until they became drowsy, and then stop counting and go on to sleep. Each Release S was told the E would be observing his EEG and would turn off the tones when S became drowsy. He was also instructed to count the tones, but only until they were silenced or he became drowsy, whichever occurred first. General experimental procedures were identical to those used for T-C and R-15 on Day 1 with the following exceptions: (a) respiration rates were not recorded, and (b) for the No-Release SS the tones were turned off when S became drowsy, i.e., alpha disappeared from his EEG for 15 s straight. Results indicated no differences in sleep onset latencies ($t_{14} = .24$) between No-Release SS (mean = 20.50, SD = 11.40) and Release SS (mean = 21.79, SD = 9.54). Therefore, the T-C Condition could not be improved by experimentally releasing an S from the counting requirement.

APPENDIX D

DATA

Day 1

Conditions	Rates	Brief	<u>Sleep</u>		Depth	<u>Breathing Blocks</u>			
			Extended			1	2	3	4
T	R-30	16.50	22.16	4		17.5	17.5	19.0	19.5
		34.00	36.33	1		12.5	14.5	16.0	16.0
		16.66	34.33	1		11.5	09.5	10.0	12.0
		23.00	23.00	4		17.5	14.0	10.0	14.0
		45.00	45.00	0		15.5	16.0	15.6	13.0
		45.00	45.00	0		16.0	16.5	16.0	18.0
	R-15	17.66	29.83	2		11.0	11.5	13.0	10.0
		03.50	03.50	4		10.0	13.0	13.5	14.0
		12.83	45.00	1		16.0	16.0	17.5	17.5
		10.16	10.16	4		14.5	16.0	15.5	14.0
		15.33	35.50	2		19.5	21.5	22.5	22.5
		04.50	04.50	4		14.0	13.0	14.5	11.5
	R-5	21.00	21.00	1		16.5	16.5	16.0	16.5
		09.50	45.00	1		27.5	25.0	23.5	24.5
		45.00	45.00	0		20.0	22.5	20.0	19.5
		25.66	32.00	1		10.0	09.5	09.5	09.0
		18.16	45.00	1		18.0	18.5	18.0	19.5
		13.16	25.00	2		05.5	11.0	11.0	10.5
	R-30	20.16	30.50	2		22.5	19.5	22.0	21.5
		19.83	19.83	4		06.5	08.0	08.5	11.5
		12.66	12.66	4		19.5	18.5	17.5	18.0
		42.83	45.00	1		17.0	17.0	14.5	16.5
		06.33	06.33	2		16.5	16.5	18.0	20.5
		18.66	18.66	4		17.0	15.5	18.0	17.5
T-C	R-15	13.00	15.50	2		13.5	15.5	14.0	13.5
		08.00	08.00	2		17.0	15.5	16.5	15.0
		12.00	21.83	4		21.5	19.0	19.0	18.5
		12.83	45.00	1		20.0	18.5	19.0	17.0
		15.66	15.66	4		15.5	18.5	19.0	19.5
		14.16	14.16	4		11.5	10.5	10.0	09.0
	R-5	19.66	19.66	2		14.5	13.5	12.0	14.0
		22.16	36.50	1		12.0	09.5	09.5	13.0
		06.50	32.33	2		23.5	23.5	23.0	23.0
		05.33	35.50	1		20.0	21.5	19.0	20.0
		10.16	45.00	1		17.5	17.5	20.5	19.5
		45.00	45.00	0		11.0	11.5	10.5	10.5

Day 1 (Continued)

Conditions	Rates	Brief	<u>Sleep</u>		Depth	<u>Breathing Blocks</u>			
			Extended			1	2	3	4
	R-30	18.00	18.00	2		29.5	30.0	29.5	18.5
		13.16	13.16	1		31.0	31.5	29.0	31.0
		18.16	18.16	4		30.5	30.0	28.0	30.5
		20.83	45.00	1		31.0	29.0	30.5	30.5
		04.50	45.00	1		17.0	16.0	14.5	14.5
		26.16	26.16	2		30.5	23.0	15.5	16.0
T-B	R-15	26.16	31.16	1		15.0	14.5	14.5	15.0
		10.16	37.50	2		15.0	13.0	12.5	12.0
		08.66	19.66	1		15.0	16.5	16.5	15.5
		37.50	37.50	1		15.0	15.0	14.5	15.0
		09.33	12.50	4		15.5	14.5	14.5	15.0
		09.16	09.16	4		15.0	15.5	15.0	15.0
	R-5	11.33	18.66	2		09.5	11.5	06.0	12.0
		05.83	05.83	4		11.0	14.0	16.0	15.0
		45.00	45.00	0		08.0	06.0	08.0	09.0
		24.00	24.00	2		05.0	07.5	06.5	06.5
		11.16	11.16	2		18.5	16.0	15.5	14.0
		45.00	45.00	0		12.0	07.0	15.5	17.0

Day 2

Conditions	Rates	Brief	<u>Sleep</u>		Depth	<u>Breathing Blocks</u>			
			Extended			1	2	3	4
T	R-30	18.83	45.00	1	19.0	22.5	20.5	20.5	
		13.16	13.16	1	12.5	14.0	12.5	15.5	
		18.50	18.50	4	13.0	12.0	12.0	14.0	
		13.66	13.66	4	16.0	15.5	14.5	14.0	
		45.00	45.00	0	16.0	16.5	16.5	16.0	
		09.16	09.16	2	14.0	13.0	15.0	16.5	
	R-15	26.33	45.00	1	11.0	13.5	13.5	11.5	
		05.33	05.33	4	13.5	13.0	13.0	14.0	
		06.33	06.33	2	17.0	18.0	19.0	18.5	
		10.83	10.83	4	12.5	18.0	20.0	19.5	
		13.50	13.50	2	20.5	18.5	21.0	22.0	
		05.83	05.83	2	13.5	13.5	12.5	12.5	
	R-5	05.16	05.16	2	17.5	19.0	19.5	19.0	
		07.50	07.50	2	26.0	22.0	22.5	22.0	
		45.00	45.00	0	20.5	20.5	18.5	18.5	
		45.00	45.00	0	07.0	09.5	08.5	12.5	
		11.00	11.00	2	16.0	19.5	18.5	19.5	
		08.00	08.00	2	10.0	12.0	14.5	14.5	
	R-30	09.33	22.66	2	23.5	23.5	23.0	21.0	
		22.16	45.00	1	10.0	13.0	15.0	17.0	
		08.83	08.83	4	20.0	18.0	17.0	16.0	
		20.16	20.16	2	14.5	17.0	15.0	17.0	
		10.50	24.00	4	15.5	15.0	19.0	22.5	
		08.66	45.00	1	16.0	14.5	14.5	14.0	
T-C	R-15	09.50	14.83	2	15.0	15.0	15.0	15.5	
		05.16	05.16	4	17.5	17.5	16.0	15.0	
		06.33	26.16	4	18.5	17.5	17.0	15.5	
		09.66	45.00	1	22.5	23.5	24.0	24.0	
		07.16	38.66	2	17.5	17.0	16.0	18.0	
		03.16	03.16	4	16.5	17.5	17.0	16.5	
	R-5	17.16	17.16	4	15.0	15.0	16.5	17.5	
		24.33	24.33	2	14.0	15.5	16.0	17.0	
		06.83	27.50	1	23.5	22.5	23.0	23.0	
		18.33	39.16	1	18.5	19.0	19.5	19.0	
		04.83	45.00	1	19.5	19.5	20.0	19.0	
		45.00	45.00	0	10.5	09.0	09.5	09.5	

Day 2 (Continued)

Conditions	Rates	Brief	<u>Sleep</u>		Depth	<u>Breathing Blocks</u>			
			Extended			1	2	3	4
T-B	R-30	05.33	05.33	4		30.5	17.5	11.5	14.5
		13.00	13.00	2		30.5	31.5	30.0	25.5
		12.83	12.83	2		31.0	31.0	25.5	28.0
		18.00	20.66	2		31.5	30.5	30.5	31.5
		45.00	45.00	0		17.0	15.5	15.5	15.5
		18.66	18.66	4		30.0	31.5	28.0	28.0
	R-15	14.33	45.00	1		15.0	15.0	15.0	14.5
		06.33	06.33	4		13.0	13.5	13.5	13.5
		18.83	18.83	2		15.0	14.5	15.0	14.5
		16.50	45.00	1		15.0	14.5	15.0	14.5
		14.33	14.33	4		14.0	14.5	14.5	14.0
		07.16	15.50	4		15.0	15.0	14.5	14.5
	R-5	29.66	32.33	2		20.5	09.0	17.5	23.0
		04.50	04.50	4		11.5	14.0	15.5	15.5
		13.66	13.66	2		09.5	13.0	11.5	12.0
		10.50	10.50	2		05.5	08.0	05.5	05.0
		07.83	07.83	4		15.0	16.0	14.0	15.5
		18.00	45.00	1		10.5	11.0	11.5	15.0

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BIOGRAPHICAL SKETCH

Paul Mallory Walker was born in Pensacola, Florida, on April 22, 1944. After graduation from Pensacola Catholic High School in 1962, he entered the Society of Jesus. His academic work for this period consisted of part-time studies at Spring Hill College in Mobile, Alabama. In 1966, he withdrew from the Society of Jesus, and at that time entered the University of Florida, from which he obtained a Bachelor of Arts degree in psychology in 1967. Since that time, he has been enrolled in the Graduate School at the University of Florida. He received the Master of Arts degree in psychology in 1969.

He is married to the former Barbara A. Black of Columbia, South Carolina. He is a second lieutenant in the army reserves, a member of Psi Chi, and student affiliate of the American Psychological Association.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.



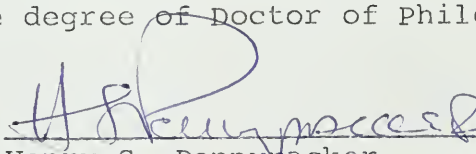
C. Michael Levy, Chairman
Associate Professor of Psychology

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Witse B. Webb
Graduate Research Professor

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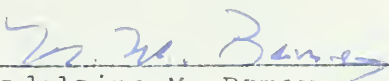
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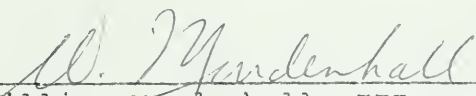
Paul Satz
Professor of Psychology

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Madelaine M. Ramey
Assistant Professor of Psychology

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William Mendenhall, III
Professor and Chairman of Statistics

This dissertation was submitted to the Department of Psychology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June, 1972

Dean, Graduate School

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